

Robust Plants' Secret? **Rubisco Activase!**

PEGGY GREB (K10078-1)



Technician Donald Brummett (left) and plant physiologist Steve Crafts-Brandner measure photosynthesis in an Arizona cotton field.

PEGGY GREB (K10082-1)



Crafts-Brandner and technician Laura Crews inspect a cotton plant that will be used in a heat-stress experiment.

Green plants can't grow without an enzyme called rubisco. Found in the cells of plant leaves, rubisco is a major player in photosynthesis. This is the process by which plants use sunlight, water from the soil, and carbon dioxide from the air to make the food that they need for growth.

Rubisco's role in photosynthesis has been known for decades. Now, however, findings from the meticulous investigations of ARS scientists shed new light on the pivotal role of another enzyme, known as rubisco activase.

Rubisco activase's main assignment is to serve as an activator and regulator of rubisco. Specifically, rubisco activase helps convert rubisco from its inactive form to its active state. That's essential. Only the active form of rubisco can help with photosynthesis. If plant cells have more inactive than active rubisco, for example, photosynthesis slows. The result: Plants don't grow as fast and our harvests aren't as bountiful.

Pinpointing Problematic Conditions

A plant could end up with more inactive than active rubisco if rubisco activase were to somehow become impaired. In fact, the hard-working rubisco activase can be undermined by certain environmental conditions, namely high temperatures and high carbon dioxide. That's what plant physiologists Steven J. Crafts-Brandner and Michael E. Salvucci have shown. Until now, no one had identified rubisco activase as the culprit that limits photosynthesis under these climatic conditions. Crafts-Brandner and Salvucci did the work at the ARS Western Cotton Research Laboratory in Phoenix, Arizona.

In the arid Southwest, where Crafts-Brandner and Salvucci are based, damaging high temperatures can occur. That's also true for the South and Southeast as well. What's more, worldwide records of the past 100 years indicate a gradual warming trend and an increase in atmospheric carbon dioxide levels. Some experts predict both trends will continue as our global climate changes.

Of the two enzymes, rubisco is more heat-tolerant than rubisco activase. And rubisco actually functions better with an increase in atmospheric carbon dioxide, the scientists report. Crafts-Brandner and Salvucci learned of rubisco activase's vulnerabilities by studying it in cotton leaves. Their analyses clarified that rubisco activase, not rubisco, is the more vulnerable of the two essential enzymes when temperatures and carbon dioxide levels increase.

Making Math-Based Models Better

These new discoveries about the nature of rubisco activase offer a novel explanation of why photosynthesis slows under those adverse regimens. Too, the findings may enhance the precision and accuracy of today's math-based models of how plants will react to climate change. Data from the Arizona

investigations can be factored into the models, adding an important new dimension that may improve the reliability of model-derived projections. The research also opens the door to new strategies that could help crop plants sidestep the unwanted, climate-driven influences on rubisco activase and the negative impacts on rubisco and photosynthesis.

Crafts-Brandner and Salvucci determined that heat and carbon dioxide work in different ways to thwart rubisco activase. Heat literally unravels the enzyme, a process known as denaturing. Unraveling renders rubisco activase unable to fit correctly onto rubisco. Lacking the correct fit, denatured rubisco activase can't efficiently convert inactive rubisco to the necessary active form. Denaturing of rubisco activase can occur at temperatures as low as 89.6°F. But rubisco continues to function effectively until temperatures reach 131°F, Crafts-Brandner and Salvucci found.

Key Energy Source Strongly Affected

High carbon dioxide impedes rubisco activase by altering levels of its favorite energy source, a high-energy compound called adenosine triphosphate, or ATP for short. Carbon dioxide levels cause a shift in the ratio of ATP to a lower-energy compound called adenosine diphosphate, or ADP. ATP and ADP occur in all living cells, including leaf cells. In the lab experiments, higher-than-normal carbon dioxide makes ADP more plentiful than ATP. This shift in the ratio of the two compounds significantly impairs rubisco activase.

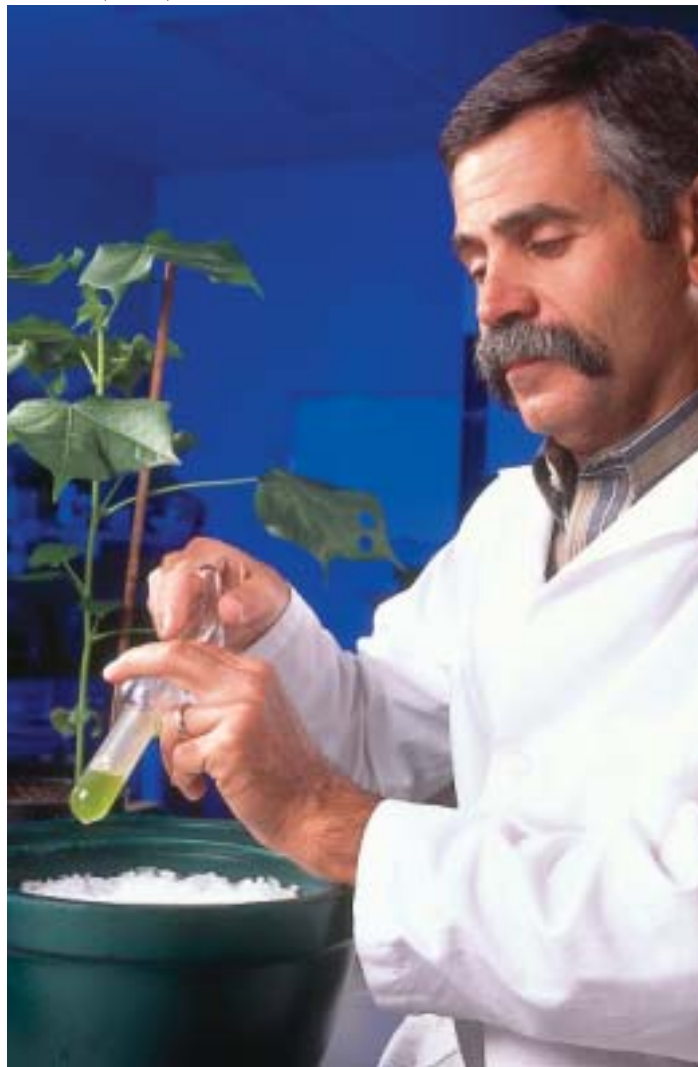
So what can be done to forestall the unwanted effects on rubisco activase? Crafts-Brandner and Salvucci hope to find or construct genes that could cue plants to synthesize a more heat-stable rubisco activase. And they plan to explore other biotech-based options that could enable rubisco activase to overcome the unfavorable shift in the ATP to ADP ratio that high carbon dioxide instigates. They're collaborating with Pioneer Hi-Bred International under the terms of a research and development agreement.

Taking Earlier Discoveries Forward

The Arizona studies build on breakthroughs made by the team of William L. Ogren, formerly with ARS in Urbana, Illinois, and now retired; Archie R. Portis, Jr., with ARS at Urbana; and Salvucci, who worked with Ogren and Portis as a postdoctoral researcher. In 1985, Ogren, Portis, and Salvucci discovered the existence of rubisco activase and proved that it activates rubisco—short for ribulose-1, 5-bisphosphate carboxylase/oxygenase. Ogren's group was the first to show that rubisco is activated and regulated by rubisco activase.

In 1990, Ogren received the coveted International Alexander Von Humboldt Foundation Award. In addition, he was selected for the ARS Hall of Fame and named to the National Academy of Sciences.

PEGGY GREB (K10083-1)



Plant physiologist Mike Salvucci prepares an extract from a cotton leaf. He will analyze the heat tolerance of key photosynthetic enzymes in the extract.

The newer work by Crafts-Brandner and Salvucci about the effects of temperature and carbon dioxide on rubisco activase was documented in the *Proceedings of the National Academy of Sciences*, one of the world's leading scientific journals.—**By Marcia Wood, ARS.**

This research is part of Plant Biological and Molecular Processes, an ARS National Program (#302) described on the World Wide Web at <http://nps.ars.usda.gov>.

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